Arthropod and Nematode Control with Aldicarb on Florida Citrus

C. C. CHILDERS, L. W. DUNCAN, T. A. WHEATON, AND L. W. TIMMER

University of Florida, IFAS, Citrus Research and Education Center,
700 Experiment Station Road, Lake Alfred, Florida 33850

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ABSTRACT Single applications of aldicarb 15 granular (G) at 37 and 75 kg/ha applied to the soil in March or April were compared with a foliar spray program and untreated control trees at four citrus grove locations for 2 yr (1983–84). Arthropod and citrus nematode population levels, tree growth, and fruit yield were monitored. Arthropods that were monitored included *Phyllocoptruta oleivora* (Ashmead) mostly on fruit, and *Eutetranychus banksi* (McGregor), *Panonychus citri* (McGregor), *Dialeurodes citrifolii* (Morgan), *Lepidosaphes gloveri* (Packard), *Cornuaspis beckii* (Newman), *Aonidiella citrina* (Coquillett), *Coccus viridis* (Green), *Parlatoria pergandii* Comstock, *Saissetia oleae* (Olivier), and *Ceroplastes floridensis* Comstock on leaves. Plant-parasitic nematodes recovered from soil and root samples were *Tylenchulus semipenetrans* (Cobb) and *Pratylenchus brachyurus* (Godfrey) Filipjev & Schuurmans Stekhoven. Aldicarb 15G at both rates provided comparable activity ranging from 13 to 20 wk control of *P. oleivora* and substantially reduced fruit injury due to russeting. Aldicarb at both rates reduced nematode populations and increased fruit yield at harvest in three of four grove sites.

KEY WORDS *Phyllocoptruta oleivora*, aldicarb, arthropod pest control, acaricide, nematode control, citrus nematode

ALDICARB IS A broad-spectrum, soil-applied carbamate pesticide with systemic activity. The compound is used to manage various insects, mites, and nematodes in several crops (Gerhardt 1966, Herne & Lund 1968, Westigard 1968). Many studies have confirmed the activity of aldicarb in arthropod and nematode pest control on citrus (Hart & Ingle 1967, Tashiro & Beavers 1967, Boling & Dean 1968, Tashiro et al. 1969, Selhime et al. 1972, Bullock 1980). Studies in Texas (Timmer & French 1979, French & Timmer 1981) demonstrated that excellent control of citrus rust mite, *Phyllocoptruta oleivora* (Ashmead), and suppression of the citrus nematode, *Tylenchulus semipenetrans* (Cobb), were obtained with aldicarb, resulting in increased fruit yield, especially at the 75 kg/ha rate. However, little published information exists regarding efficacy and citrus plant response to aldicarb use in Florida (Knapp et al. 1982).

Documentation of arthropod and nematode activity at the recommended rate of aldicarb is essential to justify use of this pesticide on Florida citrus. Our objective was to determine the effect of aldicarb on citrus production while monitoring arthropods and citrus nematodes during the 1983 and 1984 seasons. The rates of aldicarb used in the study were the maximum and minimum rates (75 and 37 kg/ha per yr) recommended for use in Florida citrus in 1983. In 1984, the recommended rates were changed, limiting aldicarb applications in Florida citrus to 37 kg/ha per yr between 1 January and 30 April to reduce the potential for groundwater contamination by the product.

Materials and Methods

Two rates of aldicarb 15 granular (G) were compared with a foliar spray treatment for arthropod pest control and an untreated control in four nonbedded citrus grove sites during the 1983 and 1984 seasons. High water tables along the coastal and flat-land wooded areas of Florida often require soil to be mounded into a series of parallel rows, each bedded sufficiently high to provide adequate drainage around the root systems of citrus trees before planting (Ziegler & Wolfe 1975). None of these groves had been previously treated with aldicarb. Treatments were assigned to plots of 20 trees arranged in a 4 by 5 grid at grove 1 and to plots of 5 trees in a 1 by 5 grid in the remaining three locations. All treatments were arranged in a randomized block design and replicated eight times. One tree per plot was sampled at each site. Replication was reduced to five plots at grove 2 and seven plots at grove 3 in 1984. Sample trees at each location were vigorous, healthy trees representative of each block. Plots were separated within and between rows by buffer trees.

Aldicarb treatments were applied in a 1.22-m band 5–7.5 cm deep under the tree canopy on two sides parallel to the row using a four-chiseled, power-fed granular applicator, side-mounted on a tractor, in 1983. In 1984, aldicarb treatments were applied on the soil surface using a tractor-drawn granular applicator with eight tubes spaced 15 cm apart and gravity fed from a Gandy box. A set of disks was spaced directly behind the delivery tubes for immediate incorporation into the soil. Adequate soil moisture was present at each site both years and irrigation of treated areas was not necessary following application of aldicarb.

Citrus cultivar and rootstocks, age, tree size and spacing, site locations, dates of aldicarb application, and harvest dates are summarized in Table 1.

Foliar spray treatments in 1983 consisted of a dilute application of 7N oil at 70 liters/ha in June or July followed by an August or early September dilute application of amitraz 180 g/liter emulsifiable concentrate (EC) at 3.9 kg/ha plus mancozeb 80% wettable powder (WP) at 5.6 kg/ha plus 7N oil at 40 liters/ha in grove 1 and 70 liters/ha in the other three groves. In 1984, fenbutatin-oxide 480 g/liter liquid concentrate (L) was applied in grove 1 at 2.8 kg/ha plus 35 liters/ha 7N oil, in grove 2 at 2.1 kg/ha plus 35 liters/ha 7N oil in August, in grove 3 at 2.1 kg/ha plus 30 liters/ha 7N oil in June, and at 1.4 kg/ha plus 23 liters/ha 7N oil at grove 4 in June.

All treatments in the 'Valencia' orange block (site 1) received 5.6 kg/ha basic copper sulphate (53% metallic), 1.1 kg/ha chlorobenzilate 480 g/liter EC, and 0.28 kg/ha of boron on 26 May 1983. Inclusion of the miticide chlorobenzilate was not intentional. In 1984, basic copper sulphate at 6.7 kg/ha was applied on 22–23 August and fenbutatin-oxide at 1.4 kg/ha on 9 November to all treatments. The 'Duncan' grapefruit block (site 2) was sprayed in July 1983 with 4.5 kg/ha of basic copper sulphate for greasy spot control. The 'Hamlin' orange groves (sites 3 and 4) received 6.7 kg/ha basic copper sulphate in June 1983. This spray was repeated in all treatments at sites 2, 3, and 4 in early August 1984. Fenbutatin-oxide at 1.4 kg/ha was applied to these same groves in early November. All pesticides in this paper are shown as formulated weights or volumes per hectare.

Twenty fruits were examined at random around the canopy perimeter of each sample tree as indicated in subsequent tables of analysis. Live motile citrus rust mites were counted within a 1-cm^2 area using a 10× hand lens on two shaded fruit surfaces on the same fruit. The two counts were combined per fruit and recorded as one observation.

Cumulative citrus rust mite-days were determined for each treatment within a grove each year by calculating the area under the population growth curve over time (Allen 1976). Mite-days were calculated using the formula $\frac{D_1 + D_2}{2}$ (SI), where D_1 and D_2 represent the citrus rust mite densities on fruit at times 1 and 2 and SI is the sample interval expressed in days. Intervals are additive to provide cumulative mite-days per treatment.

Fifty leaves from the spring flush of one sample tree per plot were picked at random around the perimeter of each sample tree at indicated time intervals before and after treatment with aldicarb. The entire upper and lower leaf surfaces were ex-

Table 1. Locations, dates of aldicarb application, and characteristics of citrus plantings

Characteristic	Citrus grove site			
	1	2	3	4
Cultivar	'Valencia' orange	'Duncan' grapefruit	'Hamlin' orange	'Hamlin' orange
Rootstock	Rough lemon	Sour orange	Sour orange	Sour orange
Tree age (yr)	22	15	18	22
Location	Davenport	Bowling Green	Bowling Green	Bowling Green
Tree ht	5.5 m	3.7–4.6 m	5.5–6.1 m	4.6 m
Spacing	7.6 by 7.6 m = 173 trees/ha	7.6 by 7.6 m = 173 trees/ha	8.5 by 6.1 m = 193 trees/ha	9.1 by 4.6 m = 240 trees/ha
Aldicarb application (1983)	29 Mar.	29 Mar.	30 Mar.	30 Mar.
Aldicarb application (1984)	2 Apr.	3 Apr.	5 Apr.	5 Apr.
Harvest (1983–84)	27 Jan.	7 Jan.	13 Dec.	22 Dec.
Harvest (1984–85)	5 Feb.	18 Jan.	8 Jan.	19 Dec.

Table 2. Control of arthropod pests with granular application of aldicarb versus foliar applications in grove 1, 'Valencia' orange in Polk County, Fla.

Treatment and formulation	kg/ha	1983 Green scale[a] 23 June	1983 Green scale[a] 31 Oct.	1983 All whitefly spp.[a] 19 Aug.	1983 Citrus rust mite[b] 7 July	14 July	2 Aug.	19 Aug.	Cumulative mite-days	1984 Citrus rust mite 6 June	10 July	16 July	30 July	9 Aug.	17 Aug.	9 Oct.	Cumulative mite-days	% rejected fruit
Aldicarb 15G	37	1.4a	1.7a	0c	0b	0b	0c	0c	71b	0b	0b	0b	0b	0	19bc	9b	701bc	28c
Aldicarb 15G	75	0.7ab	2.1a	0c	0b	0b	0c	0c	17c	0b	0b	0b	0b	0	4c	1b	150c	11d
Foliar spray	—	0.2b	0.1b	42b	3b	3b	6b	42b	2,458a	12a	0b	2b	0b	0	37b	24a	2,006b	59b
Untreated control	—	0.3b	0.4b	102a	12a	27a	78a	102a	6,369a	2b	80a	110a	17a	1	62a	22a	5,143a	74a

Means within columns followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test).
[a] Insect population densities per leaf.
[b] Citrus rust mite population density per 2 cm^2 of fruit surface.

amined for living spider mites, including *Eutetranychus banksi* (McGregor) and *Panonychus citri* (McGregor); scale insects by species, including *Lepidosaphes gloveri* (Packard), *Cornuaspis beckii* (Newman), *Aonidiella citrina* (Coquillett), *Coccus viridis* (Green), *Parlatoria pergandii* Comstock, *Saissetia oleae* (Olivier), *Ceroplastes floridensis* Comstock; and immature whitefly, primarily *Dialeurodes citrifolii* (Morgan), using a stereomicroscope.

Fifty fruits per one sample tree per plot were examined around the canopy perimeter before harvest. The cumulative percentage of surface area with russeting from citrus rust mite feeding injury was recorded for each fruit. A fruit was classified as rejected when rind blemish from citrus rust mite feeding exceeded 5% of the surface area. Freeze damage and a fungal disease, melanose, caused by *Diaporthe citri* (Fawc.) Wolf, complicated an accurate assessment of citrus rust mite-injured fruit in grove sites 1, 2, and 3 during 1983 and site 2 in 1984.

Soil samples from each plot were collected at regular intervals within the same drip line area in which the aldicarb treatments were applied. Samples consisted of ca. 250 cm^3 of soil obtained at a depth of 10–30 cm with the aid of a shovel from each of four trees per replicate. The soil from the four trees was combined, carefully mixed, and 50 cm^3 of soil per plot were subsampled and processed for the citrus nematode using a modification of Schlinder's technique (Schlinder 1961). Additional extraction methods for endoparasitic nematodes (i.e., *Pratylenchus brachyurus* [Godfrey] Filipjev & Schuurmans Stekhoven) were employed at site 1 because very low numbers of phytoparasitic nematodes were detected initially. Soil samples were collected on 1 August and root samples were collected on 25 August. Soil samples were processed for nematodes by centrifugal flotation (Jenkins 1964) and roots were incubated in jars (Young 1954) for 8 d.

Yield was determined by harvesting and weighing all fruit from two or three trees per replicate in each treatment per grove site.

In all experiments, data were subjected to analysis of variance; Duncan's (1955) multiple range test was used to separate the treatment means.

To compare the relationships between citrus yield and aldicarb dose and nematode and mite population levels, the mean relative yield (RY) for each treatment was calculated by dividing each mean treatment yield by the highest mean treatment yield within a grove. Transformed data were plotted against various independent variables and models were chosen and fitted to the data, based on observed trends.

Results and Discussion

'Valencia' Orange, Site 1. Significantly higher ($P = 0.05$) densities of green scale, *C. viridis*, occurred in both aldicarb treatments compared with the foliar sprayed and untreated trees (Table 2) in 1983. Green scale was not seen at all during 1984 in this grove.

A low population of cloudywinged whitefly, *D. citrifolii*, was present at the 25 March 1983 precount, with a gradual increase occurring through 7 July followed by a population explosion in the nonaldicarb treatments by 19 August. Excellent control of whitefly, primarily *D. citrifolii*, was obtained through 19 August with both rates of aldicarb. Spider mites, primarily *E. banksi*, and scale insect populations were never a problem on leaves or fruit in this grove during 1983.

P. oleivora did not begin increasing until 23 May 1983 followed by a sustained buildup through 19 August. Excellent control of *P. oleivora* was obtained through 19 August with both rates of aldicarb. Cumulative mite-day differences clearly reflected the magnitude of control of this mite with aldicarb compared with the foliar sprayed and untreated treatments (Table 2).

P. oleivora was not present on leaves at detectable levels before application of aldicarb in March 1984. Low citrus rust mite populations persisted through 6 June followed by a sustained buildup through July. Both rates of aldicarb were effective through early August (Table 2). A resurgence of *P. oleivora* occurred in this test during September and October. Cumulative mite-days were significantly lower for the high rate of aldicarb. Aldicarb at both rates provided excellent fruit protection from russeting compared with the other two treatments. Aldicarb at 75 kg/ha provided superior protection of the fruit from citrus rust mite injury compared with aldicarb at the low rate.

Citrus rust mite pressure was high in grove 1 during both the 1983 and 1984 seasons. Cumulative mite-days were substantially greater in the control trees in both years compared with mite-day totals in the other blocks. Both rates of aldicarb provided 20 wk of control for both years despite the presence of high citrus rust mite activity in the grove.

Significantly higher spider mite densities were recorded on 6 June 1983 in the foliar sprayed (average, three spider mites per leaf) and untreated trees (average, two spider mites per leaf) compared with the aldicarb-treated trees, which had no spider mites. These differences were of a short duration followed by nonsignificant, lower spider mite activity in the grove for the remainder of 1984. Whiteflies, primarily *D. citrifolii*, were present in low numbers in this grove until October, when populations were recorded at 14 and 13 per leaf for the foliar spray and untreated treatments, respectively. These populations were significantly greater than the whitefly densities of two and zero per leaf in the plots receiving the low and high aldicarb rates.

'Duncan' Grapefruit, Site 2. Scale insect, cloudywinged whitefly, and spider mite populations on leaves were nonexistent in this grove during 1983.

Citrus rust mite was present in very low numbers before 23 May 1983, followed by a gradual sustained increase through 3 August (Table 3). Excellent citrus rust mite control was obtained with both rates of aldicarb for 20 wk. Cumulative mite-day totals for the aldicarb treatments reflected the extent of citrus rust mite suppression compared with the other two treatments during 1983.

A high population of the cloudywinged whitefly had developed rapidly by 1 October 1984 in all treatment trees. Before that time (i.e., March through July), whitefly activity was essentially nonexistent in the grove.

Aldicarb at both rates provided excellent control of spider mites, primarily *E. banksi*, during 1984 (Table 3). Higher densities of spider mites occurred in the foliar spray trees compared with the other treatments during May and June. No differences were recorded between treatments in the fall. In contrast, a maximum of 4 wk control of *P. citri* is obtained with aldicarb on Texas citrus, often followed by a strong population resurgence (J. V. French, personal communication).

Citrus rust mite was present in very low numbers on 22 March 1984. A brief buildup occurred in early July, with citrus rust mite activity peaking on 12 July. A gradual declining population followed through early August. Population buildup was erratic in the foliar spray trees, with considerable variation occurring in mite densities during June. Variability between trees within this treatment prevented significant separation of cumulative mite-day means. Excellent citrus rust mite control was achieved for 13 wk with both rates of aldicarb during 1984.

'Hamlin' Orange, Site 3. A low cloudywinged whitefly population was present on leaves on 25 March 1983 before application of aldicarb. Population density remained low throughout the season, with a recorded peak on 23 May. Aldicarb at both rates provided superior whitefly control compared with the foliar spray treatment (Table 4). Other insect and spider mite pest populations were too low to be of concern.

Citrus rust mite activity did not begin until after 14 July, followed by a rapid increase through 17 August (Table 4). Excellent citrus rust mite control was obtained with aldicarb at both rates although population density was not high in this grove during 1983.

A higher citrus rust mite population occurred in the foliar spray trees on 13 June before treatment in June 1984 (Table 4). Aldicarb at both rates provided 15 wk control of citrus rust mite through 19 July. Citrus rust mite population pressure collapsed by 31 July in the control trees. Cumulative mite-days were comparable for the aldicarb and foliar spray treatments. However, superior fruit protection from citrus rust mite injury was obtained with the aldicarb treatments.

'Hamlin' Orange, Site 4. Cloudywinged whitefly, scale insect, and spider mite populations were

Table 3. Control of arthropod pests with granular application of aldicarb versus foliar applications in grove 2, 'Duncan' grapefruit in Hardee County, Fla.

Treatment and formulation	kg/ha	1983					1984						
		Citrus rust mite[a]					Spider mites[b]			Citrus rust mite			
		8 July	25 July	3 Aug.	16 Aug.	Cumulative mite-days	22 May	11 June	29 June	12 June	21 June	12 July	Cumulative mite-days
Aldicarb 15G	37	0b	0c	3c	3b	60c	0b	0b	1bc	0b	0b	6b	302a
Aldicarb 15G	75	0b	0c	1c	1b	27c	0b	0b	0c	0b	1b	0b	54a
Foliar spray	—	1b	9b	40b	39a	916b	1a	12a	5a	43a	60a	5b	2,885a
Untreated control	—	15a	60a	52a	24a	1,766a	0b	2b	2b	4ab	3b	43a	1,150a

Means within columns followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test).
[a] Citrus rust mite population density per 2 cm^2 of fruit surface.
[b] Spider mite (ca. 90% *E. banksi* and 10% *P. citri*) population densities per leaf.

Table 4. Control of arthropod pests with granular application of aldicarb versus foliar applications in grove 3, 'Hamlin' orange in Hardee County, Fla.

Treatment and formulation	kg/ha	1983				1984					
		All whitefly spp.	Citrus rust mite[a]			Citrus rust mite					
		23 May	26 July	17 Aug.	Cumulative mite-days	13 June	3 July	12 July	19 July	Cumulative mite-days	% rejected fruit
Aldicarb 15G	37	0b	0b	2c	98c	1b	0b	0b	3b	300ab	13c
Aldicarb 15G	75	0b	0b	1c	54c	0b	0b	1b	1b	187b	8c
Foliar spray	—	4a	0b	20b	924b	29a	1b	0b	1b	1,540a	40b
Untreated control	—	3a	7a	44a	2,222a	2b	15a	71a	47a	1,556a	70a

Means within columns followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test).
[a] Citrus rust mite population density per 2 cm^2 of fruit surface.

too low in this block to be of concern during both 1983 and 1984.

The citrus rust mite population began increasing after 14 July and peaked ca. 17 August 1983 (Table 5). Both aldicarb treatments controlled citrus rust mite for 20 wk. Cumulative mite-days for the aldicarb and foliar spray treatments were not significantly different. All three treatments provided comparable protection of fruit from citrus rust mite injury; the foliar spray was slightly superior to the low rate of aldicarb.

Citrus rust mite activity remained low until 31 July 1984. A late summer buildup followed in September and October, resulting in comparable mite-day levels in the aldicarb and foliar spray treatments (Table 5). A significantly lower percentage of rejected fruit was obtained with aldicarb at 75 kg/ha compared with the foliar spray. Both rates of aldicarb provided comparable protection of the fruit.

Nematode Control. Moderate *T. semipenetrans* infestations existed in groves 2–4, whereas the nematode was never detected in grove 1. However, relatively high infestations of *P. brachyurus* were detected in grove 1 in soil ($\bar{x}$ = 262 per 100 cm^3 soil) and root ($\bar{x}$ = 109 per 1 g root fresh weight) samples collected from control plots in August 1985.

Both rates of aldicarb reduced populations of *T. semipenetrans* (Fig. 1) and a clear dosage response was evident. A paired *t* test on log-transformed data pooled by treatment indicated higher (t = 2.19; df = 23; $P < 0.025$) mean population levels in plots that received the low ($\bar{x}$ = 506 nematodes per 100 cm^3 of soil) rather than the high ($\bar{x}$ = 362 nematodes per 100 cm^3 of soil) aldicarb dosage during the experiment. When *T. semipenetrans* population levels in groves 2–4 were standardized with respect to control populations and pooled within treatments for each observation date, mean annual population reduction due to 37 and 75 kg/ha aldicarb was 77 and 85%, respectively. The regression equation $\log_e y = [-0.427 \log_e (x + 1)] - 0.080$, where y is mean 1985 treatment population level per mean 1985 untreated control population level blocked by site and x is aldicarb dose, explained 95% of the 1985 nematode population variability ($P < 0.01$; $n = 12$). *T. semipenetrans* population growth was inhibited in aldicarb-treated plots for ca. 4–5 mo after each treatment. Mean population levels in those treatments were never higher than 60% of levels in nontreated plots at any time during the experiment. Soil and root population levels of *P. brachyurus* treated with 37 kg/ha aldicarb were 90 and 91% lower, respectively, than untreated control population levels. A further significant reduction to 100 and 99% below untreated soil and root populations, respectively, resulted from the 75 kg/ha treatment.

Fruit Yield. Severe freezes occurred in central Florida in December 1983 and January 1985, resulting in substantial yield reductions at all test sites in 1984 and in the 'Valencia' site in 1985. Aldicarb

Table 5. Control of arthropod pests with granular application of aldicarb versus foliar applications in grove 4, 'Hamlin' orange in Polk County, Fla.

Treatment and formulation	kg/ha	1983					1984					
		Citrus rust mite[a]					Citrus rust mite					
		26 July	3 Aug.	17 Aug.	Cumulative mite-days	% rejected fruit	3 July	31 July	18 Sept.	2 Oct.	Cumulative mite-days	% rejected fruit
Aldicarb 15G	37	1b	1b	4b	165b	4b	0b	2b	8b	18b	730b	3bc
Aldicarb 15G	75	0b	1b	2b	170b	2bc	0b	1b	5b	10b	440b	1c
Foliar spray	—	3b	19a	17b	763ab	1c	0b	0b	9b	24ab	853b	10b
Untreated control	—	16a	32a	37a	1,495a	15a	5a	6a	25a	47a	1,919a	24a

Means within columns followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test).
[a] Citrus rust mite population density per 2 cm^2 of fruit surface.

Table 6. Individual year and cumulative year yields in kilograms per tree for 1983, 1984, and 1983 + 1984 in four citrus grove sites in Florida

	Cumulative[a]		
	1983–84	1984–85	2-yr
Site 1. 'Valencia' orange (173 trees/ha)[b]			
Aldicarb at 37 kg/ha	173a	131a	305a
Aldicarb at 75 kg/ha	148a	133a	283a
Foliar	157a	60b	218b
Untreated	139a	75b	215b
Site 2. 'Duncan' grapefruit (173 trees/ha)[b]			
Aldicarb at 37 kg/ha	493a	194ab	730b
Aldicarb at 75 kg/ha	565a	276a	879a
Foliar	510a	162b	688b
Untreated	535a	161b	703b
Site 3. 'Hamlin' orange (193 trees/ha)[b]			
Aldicarb at 37 kg/ha	430a	391a	820a
Aldicarb at 75 kg/ha	408a	392a	810a
Foliar	387a	356ab	740b
Untreated	385a	325b	706b
Site 4. 'Hamlin' orange (240 trees/ha)[b]			
Aldicarb at 37 kg/ha	379a	186a	571a
Aldicarb at 75 kg/ha	398a	195a	595a
Foliar	392a	148a	543a
Untreated	379a	169a	552a

Means within columns followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test).

[a] Cumulative yields differ slightly from combined year totals because of rounding off decimal values.

[b] Yields for the 1983–84 and 1984–85 seasons were obtained from eight replications versus five for the 1984–85 season in site 2. The cumulative yields are based on the same five replications only for the 1983–84 and 1984–85 seasons in site 2 and seven replications in the 1984–85 season in site 3.

at both rates resulted in significantly greater 2-yr cumulative yields in sites 1, 2, and 3. Site 4 had higher cumulative yields but treatment differences were not significant (Table 6). Yield increases for the aldicarb over the other treatments for the 2-yr period per grove site averaged 13,343 kg/ha at site 1, 17,662 kg/ha at site 2, 17,741 kg/ha at site 3, and 8,592 kg/ha at site 4.

A dose response curve, $RY = 0.79 + 0.0028x$, where x is aldicarb dose, explained 61% ($P = 0.01$) of the relative yield variability. Seinhorst's (1965) model of the relationship between plant growth and nematode population level (P), $RY = 0.67 + 0.33 \times 0.9992^{(P-240)}$ for $P > 240$ and $RY = 1.0$ for $P \leq 240$, explained 73% ($P = 0.01$) of the variability in relative yield when P = mean 1985 population levels of *T. semipenetrans* in groves 2–4. The relationship between cumulative mite-days on fruit in 1985 (x) and relative yield (y) was best described by the linear regression $y = 0.94 - 0.00007x$ ($r^2 = 0.18$; $P > 0.05$). When *T. semipenetrans* population level and aldicarb dose were considered in the multiple linear regression model, $y = 0.93 + 0.001x_1 - 0.00008x_2$ ($r^2 = 0.77$; $P = 0.01$), where x_1 is aldicarb dose and x_2 is mean 1985 population level, only *T. semipenetrans* population levels explained significantly more variability as the additional variable.

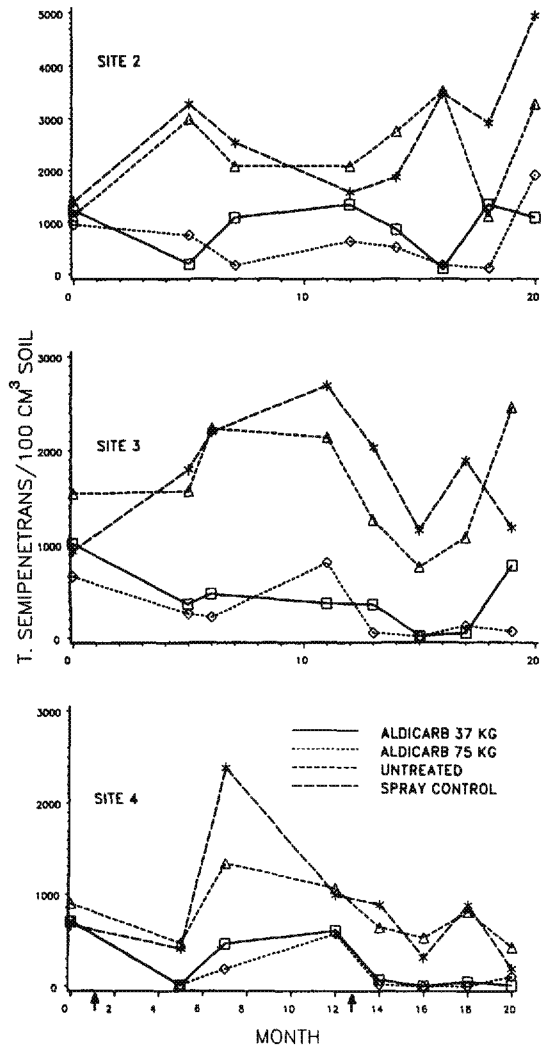

Fig. 1. Average population levels of *T. semipenetrans* per 100 cm³ of soil at sites 2, 3, and 4 during a period of 20 mo. Treatments consisted of aldicarb 37 kg/ha (□), aldicarb 75 kg/ha (◇), spray program (*), and untreated control (△). Aldicarb application is indicated by (↑) below the abscissa.

P. brachyurus is a common parasite of Florida citrus and is pathogenic on seedlings (Brooks & Perry 1967, Tarjan & O'Bannon 1969, Radewald et al. 1971, Tommerlin & O'Bannon 1973, Fredrick & Tarjan 1975) and young trees (O'Bannon et al. 1973). Although the pathogenicity of this species seems to diminish with tree age (O'Bannon et al. 1973), present results indicate that further work is needed to establish the importance of *P. brachyurus* infestations in mature groves. Freeze damage to trees during the present experiment may have predisposed trees to greater damage from *P. brachyurus* parasitism than is ordinarily associated with the nematode in mature citrus.

In conclusion, citrus rust mite was the most important arthropod pest on fruit in all four groves during both 1983 and 1984. Significantly higher resurgence of citrus rust mite occurred in the foliar spray plots during June 1984 in three of four grove sites compared with the aldicarb and untreated control treatments. There were no indications of resurgence problems with any other arthropod species. Based on arthropod assessment and yield response, aldicarb at 37 kg/ha provided excellent arthropod control that was comparable with aldicarb at 75 kg/ha in three of the four grove sites. Both aldicarb rates effectively suppressed population levels of *T. semipenetrans* and *P. brachyurus*. The regression analyses supported the possibility that some of the yield variability associated with aldicarb treatment was due to suppression of *T. semipenetrans* population levels. However, because nematode population levels varied directly with aldicarb dose, other unmeasured factors may have been similarly affected. Thus, the present data are insufficient to portion the relative effects of nematode and arthropod communities on citrus yield. Effective citrus pest management requires that future studies address this question. Additional research is also needed to determine whether differences in arthropod and nematode control and subsequent effects on fruit yield and quality occur with specific timing of aldicarb application on Florida citrus.

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